EXPERIMENTAL RESEARCH ON MACHINING WITH SELF PROPELLED ROTARY CUTTING TOOLS

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INTRODUCTION

The main feature of a rotary cutting tool is the circular form of the chisel and its possibility to make a self propelled rotation. This rotary motion is achieved due a particular position of the tool axis in regard with the main cutting direction and the workpiece surface. Recently this kind of tools received more interest from the specialists due to the technological advantages they can bring, mainly:

- high tool lives;
- low tool temperatures;
- high surface quality;
- possibility to cut low machinability materials.

1. GENERAL FEATURES OF SURFACES MACHINED WITH SELF-PROPELLED ROTARY TOOLS STAR

Due to the big radius of the tool, the STAR tools (fig. 1) can achieve theoretically, surfaces with lower roughness then the conventional one point cutting tools when the same feed is used.

The researches on surface roughness machined with STAR tools presented the dependence of surface quality of several factors as:

- the particular position of tool axis which together with feed movement influences the geometrical roughness profile;
- the plastic deformation during chip formation;
- the cutting effect due the edge rotary movement;
- the copying of micro-profile of cutting edge;
- the presence of out of run of the rotary edge Δr.
- the altered position of cutting edge s1 due the clearance within the rotary tool bearings.

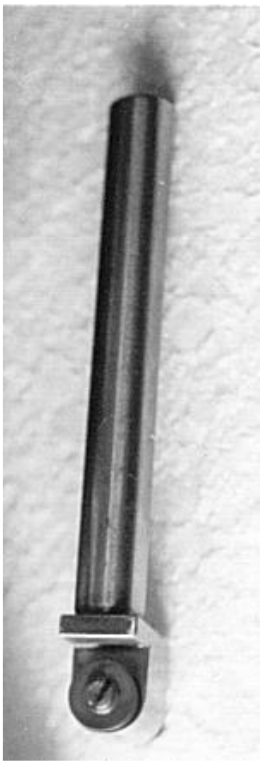


Figure 1. Rotary cutting tool STAR.

For calculating the maximum peak-to-valley roughness R_{max} the following equation is proposed in [3]:

$$R_{max} = \frac{\left[f + (\Delta r + s_1)\cdot \cos^2\lambda\right]^2}{8\cdot r\cdot \cos^2\lambda} \tag{1}$$

where:

r – tool radius;
λ – angle of the tool axis;
Δr – clearance within tool bearings;
s_1 – edge movement in the feed direction:
f – feed.

As in case of conventional tools, equation (1) does not contain the influence of cutting speed. In order to achieve a full analytical model able to preview the roughness of machined surface costly experimental programs are needed.

2. EXPERIMENTAL DESIGN AND SETUP

Using Taguchi's methodology and an experimental fractional design, the number of experimental runs is minimized [1]. From the three quality characteristics of Taguchi's methodology, for the analysis of machined surface roughness, "the smaller–the-better" has been chosen. The aim of the

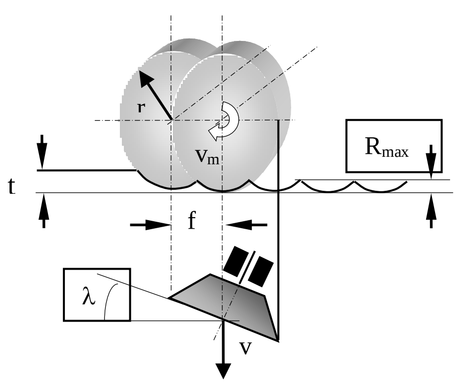


Figure 2. Peak-to-valley profile of the machined surface

experimental program was to analyze the factors that could influence the roughness and to find the optimum combination of the factors in order to minimize the peak-to-valley roughness of the machined surface.

Because the tool radius has definitely known influence on roughness, and its magnitude is mainly established from geometrical reasons being connected with the geometrical features of the radial and thrust bearings, it hasn't been introduced in the analysis. In the same time the depth of cut wasn't discussed too, because its limited influence on roughness. As it is presented in figure 3, the

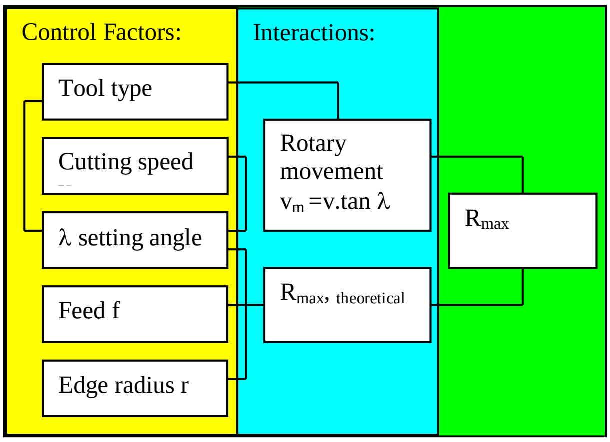


Figure 3. Factors influencing roughness.

main factors and their interactions, considered to be important for generating a smooth surface were: the cutting speed - v, the axis angle - λ, the feed – f, and the tool type considered by the two cases when the rotary tool is self propelled and when the rotary tool is blocked. Interactions of factors have been considered too: "cutting speed v with angle λ", because they produce the edge speed v_m, "feed f with λ angle, because they influence the theoretical peak-to-valley roughness, and the tool type (self-propelled or blocked) and λ angle doe geometrical interactions.

The experimental program was carried out using a shaping machine SH425, using a self-propelled rotary tool STAR with the characteristics presented in table 2.

For the experimental tests 100 x 50 x 20, AlCu alloy work pieces were used. The roughness measurement was made using a Hommel T1000 Roughness Tester.

3. ANALYSIS OF EXPERIMENTAL RESULTS

The experimental runs were randomly done and then analyzed with the help of dedicated software for Taguchi methodology – Qualtek4. An orthogonal array L8, with four factors, three interactions and two levels has been used (tab.3) [1].

Table 1.

Tool	**Bearings**	**Manufacturer**	**Cutting insert**
STAR 16	1 radial with needles RHNA 101410	URB Romania	RDHX1604MOT/SBF P25 BÖHLERIT, Germany
	2 thrust bearing with needles.	BSL - Anglia	

Table 2

Factor	UM	Code	Level 1	Level 2
Tool type	-	**A**	**self-propelled** (1)	**blocked** (2)
Cutting speed v	m/min	**B**	5,6	11,6
Feed f	mm/ stroke	**C**	0,4	0.8
Angle λ	o	**D**	30º	45º

The orthogonal array of the Taguchi experimental setup **L8**, filled with the measured values of response variable are presented in table 3. The three values for Rmax have been obtain measuring the peak-to-valley roughness in a direction parallel with the feed direction, and "signal-to-noise", S/N ratio, for each experimental run has been calculating using equation (2):

$$S / N = -10 \cdot log\left(s^2 + \bar{y}^2\right) \qquad (2)$$

where:

s - is the standard deviation of measured values, and

$\bar{y}$ - the average of measured roughness values.

The influence of control factors have been carried out by using the ANOVA analysis. The main factors affecting the roughness have been identified and presented in table 4 and figure 4.

Table 3

Exp. No.	Factors				Interacti			Measured R_{max}	
	A	B	C	D	A D	B D	D C	Ave.	s
1	1	1	1	1	1	1	1	4,466	0,585
2	1	1	1	2	2	2	2	7,533	0,351
3	1	2	2	1	1	2	2	7,366	0,251
4	1	2	2	2	2	1	1	8,133	0,152
5	2	1	2	1	2	1	2	5,2	0,264
6	2	1	2	2	1	2	1	6,4	0,458
7	2	2	1	1	2	2	1	13,466	0,896
8	2	2	1	2	1	1	2	17,933	0,404

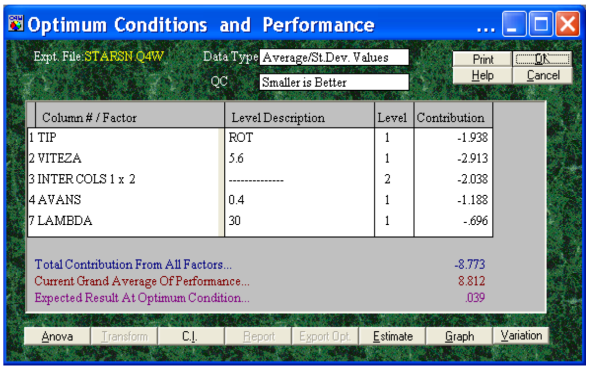


Figure 5. The optimum working conditions

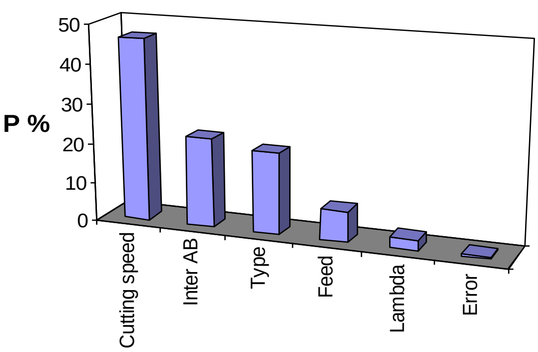
Table 4.

Col #/Factor	DOF(f)	(S)	(V)	F –Ratio (F)	Pure Sum (S')	Percent P(%)
1 A	1	90.093	90.093	1006.762	90.004	20.437
2 B	1	203.583	203.583	2274.925	203.494	46.208
3 inter AB	1	99.633	99.633	1113.347	99.544	22.603
4 C	1	33.843	33.843	378.183	33.754	7.664
5 inter AC	(1)	(1.26)		Pooled	(CL=99.99%)	
6 inter BD	(1)	(0.35)		Pooled	(CL=99.99%)	
7 D	1	11.62	11.62	129.85	11.53	2.618
Others/ Error	18	1.61	0.089			0.47
Total	23	440.386				100.00%

4. OPTIMAL WORKING CONDITION FOR STAR TOOLS

The optimal cutting conditions for machining with self-propelled rotary tools, conditions that produces the best surface quality Rmax, may be found by taking in account the main effects of the control factors that are producing insensibility to the S/N ratio.

For the achieved experimental program, the optimal machining conditions recommended by Qualtek4 are presented in figure 5.



5. CONCLUSIONS

The experimental program confirmed the conclusions of other theoretical approaches in modeling the influences of factors upon the machined with self-propelled rotary tools surface roughness. Using the Taguchi methodology, the optimal working conditions have been identified, with respect of cutting speed, feed and λ angle. The obtained results confirm the fact that the peak-to-valley roughness is mainly influenced by the value of feed. The presence of rotary motion of the edge is smaller in effect then the feed. The λ angle generating affects via the curvature radius of the generating profile of the tool. The optimal combination have been verified through validating experimental runs in 97% cases, confirming that Taguchi methodology was an appropriate way to perform an efficient analysis of the self-propelled cutting tool action.

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